LASER POWER
RESEARCH

Digital Image Profilers For Detecting Faint Sources Which Have Bright Companions NAS7-1103

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1.0 Project Summary

A breadboard image profiling system developed for the first phase of this project has demonstrated the potential for detecting extremely faint optical sources in the presence of bright companions. Experimental data derived from laboratory testing of the device supports the theory that image profilers of this type may approach the theoretical limit imposed by photon statistics.

The objective of Phase II of this program is the development of a ground-based multichannel image profiling system capable of detecting faint stellar objects slightly displaced from brighter stars. Over the course of the last three months, we have finalized the multichannel image profiling system and attempted three field tests.

2.0 Background

Faint optical sources in the presence of bright companions are difficult to discern with conventional optical detectors. The point spread function appears superimposed upon the background radiation from the brighter source. However, detectors measure the total flux at each point in an image, rather than measure small variations in intensity relative to adjacent points in the image. Thus, in order to detect a faint optical source that is located in close proximity to a brighter source, it is necessary to develop a detection system which is capable of distinguishing very small fractional variations in radiation flux.

The multichannel image profiling system being developed within the present program potentially can reach the detection limit imposed by the quantized nature of photoelectron statistics. To accomplish this, the system performs many scans of the image area; storing the photoelectron counts from each element of the image in digital form. Angular jitter in the optical system line-of-sight is normalized and, independent of the number of detectors employed. Each detector scans the entire image during the course of one scan. These factors aid in improving the signal to noise ratio of the instrument.

The Phase I program encompassed the design, construction and testing of a single-channel image profiler and the design and construction of a multisource test system. Throughout the performance of the first phase of the project, there was an ongoing analytic effort directed toward

parametric refinement of the image profiling technique. The results of the modeling activities of Phase I have been used as a guideline for the development of a system design for the proposed multichannel breadboard.

The Phase II image profiling system incorporates an array of slit-formed fiber bundles which lie side by side; the scanned image passing over each aperture in succession. Each aperture is complemented by a photomultiplier, a preamplifier, a discriminator, a prescaler, a shift register, and a single channel incremental count accumulator. Thus, multiple channels operate in parallel to the point where the counts from individual accumulators are summed in a multichannel system accumulator.

As noted earlier, the ability of an ideal profiling system to detect a faint source is set by the statistics of the photon counts which make up the background in the immediate vicinity of the source. The extent to which the performance of a real system approaches the ideal depends on the types of errors present in the system; constant and time varying. Sources of error that are constant with time can be compensated. This leaves sources of error that are time varying. By conducting calibration runs with respect to known singular optical sources and comparing them to the profile of an unknown source, time varying systematic errors can be minimized. Assuming that the variability of systematic errors is maintained at a negligible level for the time required to perform a calibration/ measurement run, the precision achievable with a multichannel digital profiling technique is dependent only upon the fundamental statistics of the photon detection process.

When the above criteria is met, an ideal multichannel system with an integration time on the order of one minute is potentially capable of detecting a 16th magnitude secondary optical source at a displacement of 0.04 arcsecond from a 6th magnitude primary source. Also it is potentially able to detect a secondary of magnitude 18.5 at a displacement of 0.2 arc second from a 6th magnitude primary.

1.0 Progress Made against Milestones

Over the course of the last quarter, the LPC team completed the digital image profiler and attempted three separate field tests.

2.0 Results, Conclusions and Recommendations

Work proceeded at a furious pace during mid-August to prepare the instrument for its maiden run at the focal plane of the 24" telescope located at Table Mountain Observatory. Over the course of the last quarter, we made three separate trips to Table Mountain Observatory. The first two trips were plagued by telescope mechanical problems and poor weather conditions. The third trip was more successful.

2.1 Scan Mirror Difficulties

During a final system checkout, a severe velocity ripple was noted in the rotary motor used to operate the scanning mirror. After contacting the distributor, we learned that the motor unit had been modified with an EPROM that re-mapped the dip switch settings for various step resolutions. Therefore, when we selected a step resolution of 25,000 steps per revolution, we obtained 14,000. Selecting 18,000 steps per revolution was in reality 50,008 steps per revolution. These departures from the indicated step resolutions resulted in unpredictable velocity measurements since the motor velocity is based upon the steps per revolution of the motor.

The currents in each phase winding of a micro-stepping motor are controlled continuously, rather than discretely commanded on and off. Continuous modulation of the currents in each phase winding leads to cyclic positional errors which cause a velocity modulation. Operating the motor at or near the natural resonance frequency of the system results in a serious resonance condition.

Unfortunately, resonance conditions occur at motor speeds between 0.1 and 1 revolution per second. The profiler was designed to operate at speeds between 0.16 and 1.2 revolutions per second.

Parker Compumotor replaced the A series motor and drive unit with an S series motor and drive. The S series motor and drive are inherently more stable and reliable than their A series counter-

parts. The S series drive unit is configured at the factory to operate at step resolutions from 800 to 25,000 steps per revolution. Additionally, the engineer provided us with a viscous damper to attach to the motor and taught us how to tune out the critical harmonic components of the resonances and find a quiet range of motor speeds.

After tuning the new motor and drive unit using a tachometer and an oscilloscope to minimize the velocity ripple, we arrived at two speeds that would provide acceptable performance.

Table 1— Revised Motor Speeds

Motor (rev/s)	Facet (steps/s)	Frame Rate (Hz)	Single Channel Exposure (ms)
0.50	25,000	25	32
1.00	50,000	50	16

At the present time, the software runs the new motor at these speeds. The vendor is working with the distributor to provide us with a direct exchange the A series drive and motor with the S series drive and motor. We are currently in possession of both units.

2.2 First Trip to Table Mountain Observatory
Our first trip to Table Mountain observatory was plagued by problems that were, for the most part, out of our control. During the first two days of our three day stay, the facility suffered from an electrical brown-out condition. The brown-out impaired the operation of the dome, telescope and hydraulic floor. This condition confined our observing to a narrow strip of sky and a few degrees of declination. Electricians dispatched from JPL discovered a corroded breaker. By Friday night, the problem was relieved and the facility was fully functional.

2.3 Field Modification to the Optical Train
The original optical layout of the digital image profiler included a CCD located at an intermediate focal plane in our instrument. This CCD was beyond the microscope objective wheel and before the scanning mirror and, with a 5x microscope objective in line, was designed to have a 20 arcsecond field of view. During previous trips to Table Mountain observatory and conversations with the resident astronomer, it was our understanding that the pointing accuracy of the telescope was approximately 10 arcseconds. That is, we could accurately position the image of a

star on our instrument within a 10 arcsecond circle. During our first week at the observatory, it became apparent that this was not the case. There is apparently no consistent relationship between the sighting scope and the telescope from trip to trip. The field of view of the CCD camera was far too narrow to enable us to capture a stellar image. We quickly realized that the CCD could not be used to locate the stellar image.

We performed a field modification to the instrument to overcome the narrow field of view problem. The microscope objective wheel is bored with twelve threaded holes to accommodate twelve microscope objectives and filters. In order to obtain the widest field of view, we sacrificed one of the 20x microscope objectives and substituted a 45° turning mirror assembly in its place. We mounted a post to the X-Y stage assembly that passed through the center of the objective wheel. The CCD was fixed at the end of the post and facing the turning mirror. This modification can be seen in Figure 1.

Figure 1 — Field Modification
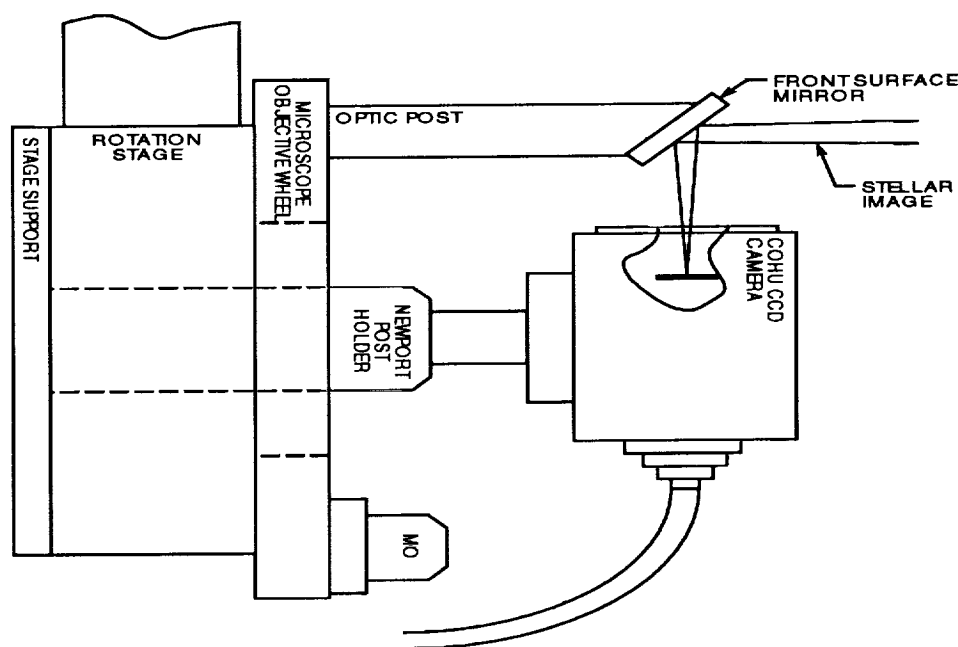
With the CCD referenced to the X-Y stages, the microscope objective selection process would be limited to determining focus only. Fortunately, with the image passing to the final focus of our

instrument, we could use the image profiles themselves to determine whether we were focused or not.

2.4 Preliminary Experimental Results

With the field modification in place, we tested the image profiling acquisition system utilizing actual stellar images. We selected Lyr-Alpha Vega as our primary target due to its very bright magnitude. The 24" telescope was commanded to the R.A. and Declination coordinates associated with Vega (R.A.:18° 34' 57", Dec: 38° 07' 46") and the star appeared onscreen at the Macintosh. As was mentioned previously, the system software was modified to incorporate a routine to select the 45° turning mirror which passed the image on to the CCD. Unfortunately, we were not able to position the mirror and the CCD surface such that a focused image at the CCD represented a focused image at the fiber bundle.

With the star centered on the optical axis of the profiler, we selected a 5x microscope objective and acquired scans of Vega. Figure 2 is a consolidation of 4 separate profiles of the star taken over a 15 minute interval and normalized to the total number of counts in each profile. These
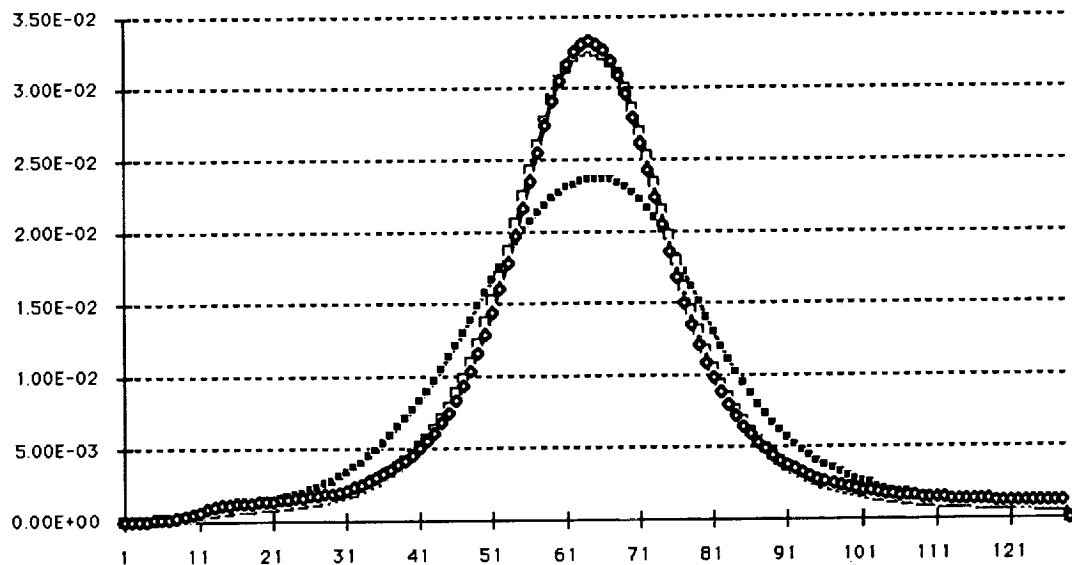
Figure 2— LYR-Alpha Vega, Normalized Data Profiles

scans were obtained at a rate of 25 scans per second and represent the accumulation of 4000 scans per profile.

Notice that one of the scans is broader compared to the other. The broad scan is the first scan obtained of Vega and as such was out of focus. Using the scan width as a measure of defocus, we adjusted the focus of the 5x objective until we obtained the narrowest profile.

Satisfied with the performance of the instrument with a 0 magnitude star, we turned out attention to dimmer stars. We selected a binary pair in Cygnus as our next candidate. Cyg Delta is a magnitude 2.87 star with a magnitude 6.5 stellar companion. The angular separation of the pair is 2.2 arcseconds. We arranged the profiler to scan the pair to maximize the detection of the secondary. Figure 3 represents two data sets of Cyg-Delta of 1000 scans cumulative each. Each profile was normalized to the total number of counts in the scan. In the figure you will notice a shoulder to the profile. This shoulder was not apparent in the Vega profile. However, with dimmer stars, it appears consistently. We suspected that the shoulder represented a digital noise
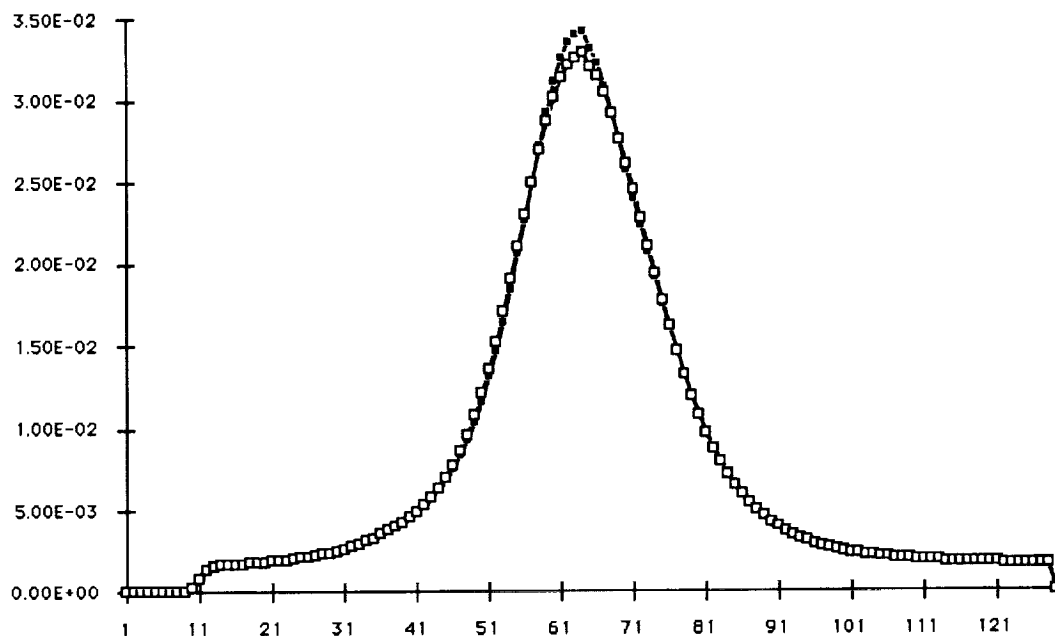

Figure 3— Cyg—Delta, Normalized Data Profiles

problem, and hoped that the problem was not a result of damage to the unit caused by the brown-out in the facility. The noise was significant enough to suppress the signal of the secondary in Cyg-Delta. As a matter of fact, we were unable to locate stars with magnitudes fainter than 5.

Figure 4 is a screen shot of a bright star in Pegasus. In this figure each of the problems associated with our first trip can be seen. The image of the out of focus star (doughnut shaped due to the Cassegrain design of the telescope) is visible in the right-hand corner of the figure. The profile clearly indicates the high number of noise counts in the wings as well as the curious shoulder in the left-hand side of the profile. The status bar at the bottom of the figure provides information regarding the number of scans per second, number of profiles accumulated, peak count and other important information.
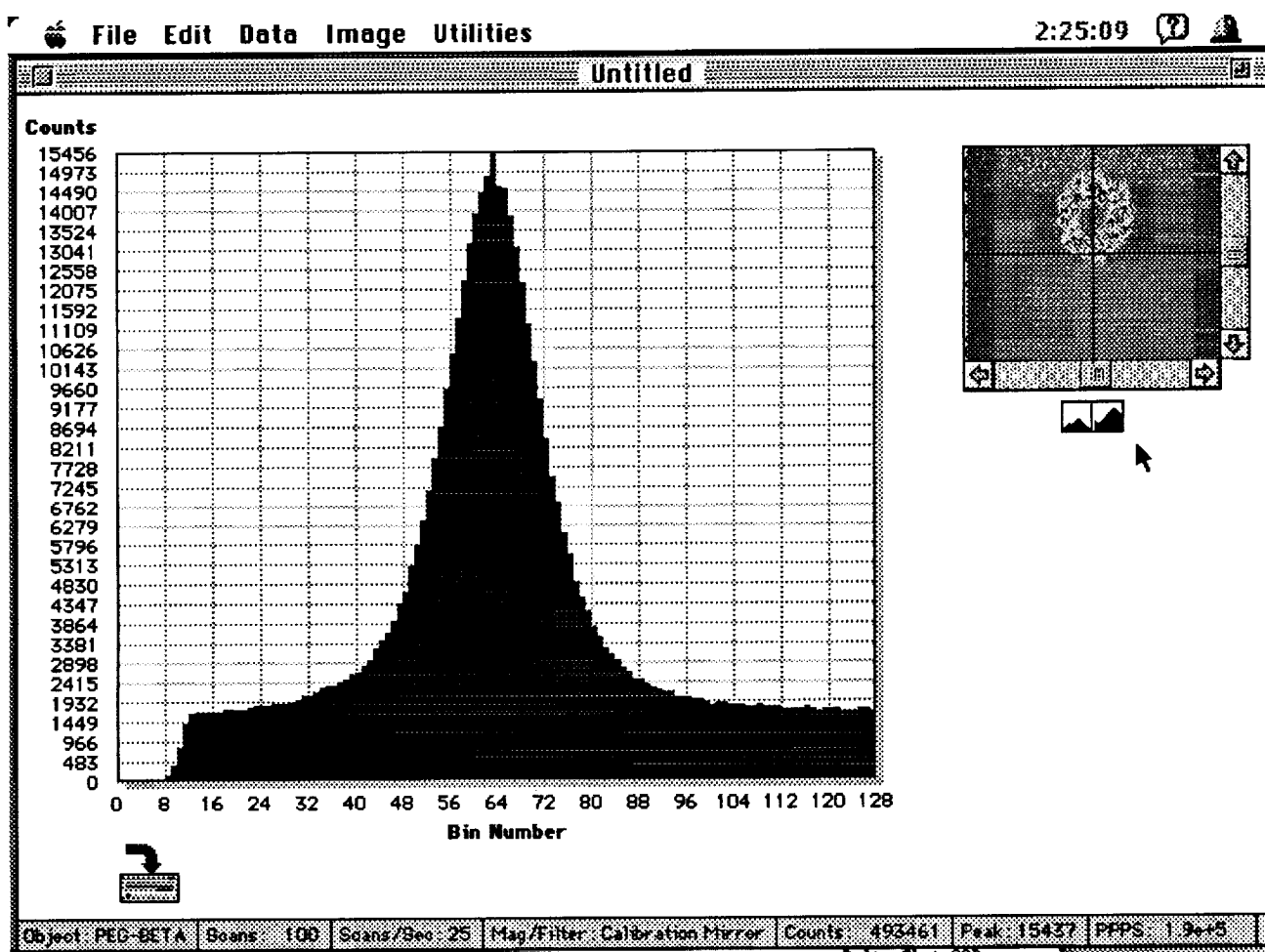

Figure 4— Peg—Beta Screen Shot

Owing in part to the brown-out condition at the telescope facility, we were able to secure the following week on the 24" telescope. We returned to San Diego with information regarding the electronics noise and a new understanding of the optical train.

## 2.5 Lab Modification to the Optical Train

We returned to San Diego on Saturday, August 31 with the optical head unit and the motor controller for the X,Y stages and the rotary wheel. Our goal was to determine the X,Y coordinates for a nominal focus of a 5x and 10x microscope objective. The experimental set-up utilized a green helium neon laser (wavelength 543.5 nm) with a power of 1.1 milliwatts located at one end of a 50 foot optical bench. The beam was focused by a 1 meter focal length lens and allowed to diverge to a diameter of approximately 5 mm. The divergent beam was then refocused by a 200 mm focal length lens and brought to focus a the working distance of the 5x objective (approximately 25 mm). Utilizing the motion control digital readout, we adjusted the focus of the 5x until we achieved a sharp focus at the fiber bundle. The number of steps required to achieve focus was recorded and later coded into software. This procedure was repeated for each of eight microscope objectives. With this information in hand it was now possible to return to the mountain secure in the knowledge that an image located at the center of our optical axis by the CCD/mirror assembly would automatically be brought into focus.

2.6 Second Week at Table Mountain

To address the electronics noise issue, we brought our electronics expert, Mike Landry, to Table Mountain. During our second stay, Mike Landry and Elena Morris began systematically evaluating the performance of each of the eight boards, and each of the 64 channels. We located and dispatched sources of noise that included loose connections and dead or intermittent amplifier channels. We also discovered that the CCD camera contributed to the noise problem. Figure 5 is a profile of the noise introduced by the CCD camera only with no high voltage to the PM tubes.

The signal from the camera is picked up and amplified by the variable gain amplifiers thereby creating a periodic signal even when the high voltage is off. This information enables us to avoid this source of error in our data by limiting our use of the camera to aligning the star only.

Figure 5— CCD Noise Contribution
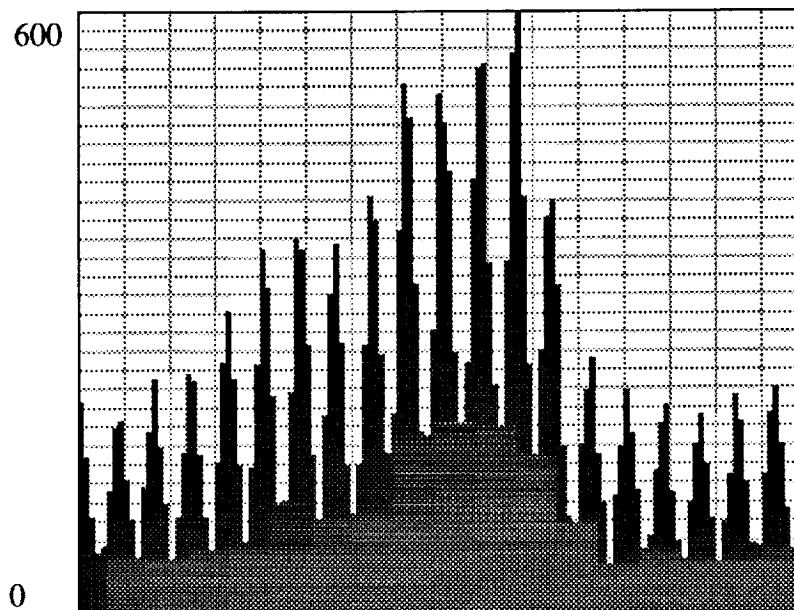
Finally, we adjusted the gain and discriminator thresholds for all 64 channels to provide the smoothest profile obtainable. The procedure was very time consuming, but we completed the job by sunset. Unfortunately, bad weather made it impossible to test the unit against a star.

Bad weather cut short our second field test. We stored the instrument in the storage closet at the 24" telescope at Table Mountain so that it would be on hand for our next visit.

2.7 Third Field Test at Table Mountain

A third field test was necessary to evaluate the performance of the profiler after our electronic tune-up procedure. The profiler had remained in storage at the 24" telescope facility at Table Mountain, and, to our knowledge, had not been moved.

The third field test was originally scheduled to last for four consecutive nights, but again, bad weather conditions cut short the observing schedule.

During our third stay, we were able to obtain data. However, the seeing conditions were quite bad. High gusty winds and a light cirrus cover made for about three to four arcsecond seeing

conditions. Under normal circumstances, the Strehl intensity selection criterion option we have developed in software would have been used to obtain only the cleanest data profiles, however, we were still uncertain about the general behavior of the profiler, and did not wish to risk throwing away any data that might enable us to diagnose potential problems. Further, we realized that the poor seeing conditions significantly reduced the likelihood of detecting anything but optical binaries.

We decided to use Andromeda Gamma as our test binary. Andromeda Gamma has a primary star with a visual magnitude of 2.12 and a secondary star with a visual magnitude 5.08. The angular separation of the two stars is quoted in Burnham as 10 arcseconds maximum with a 0.5 arcsecond separation occurring in 1991.
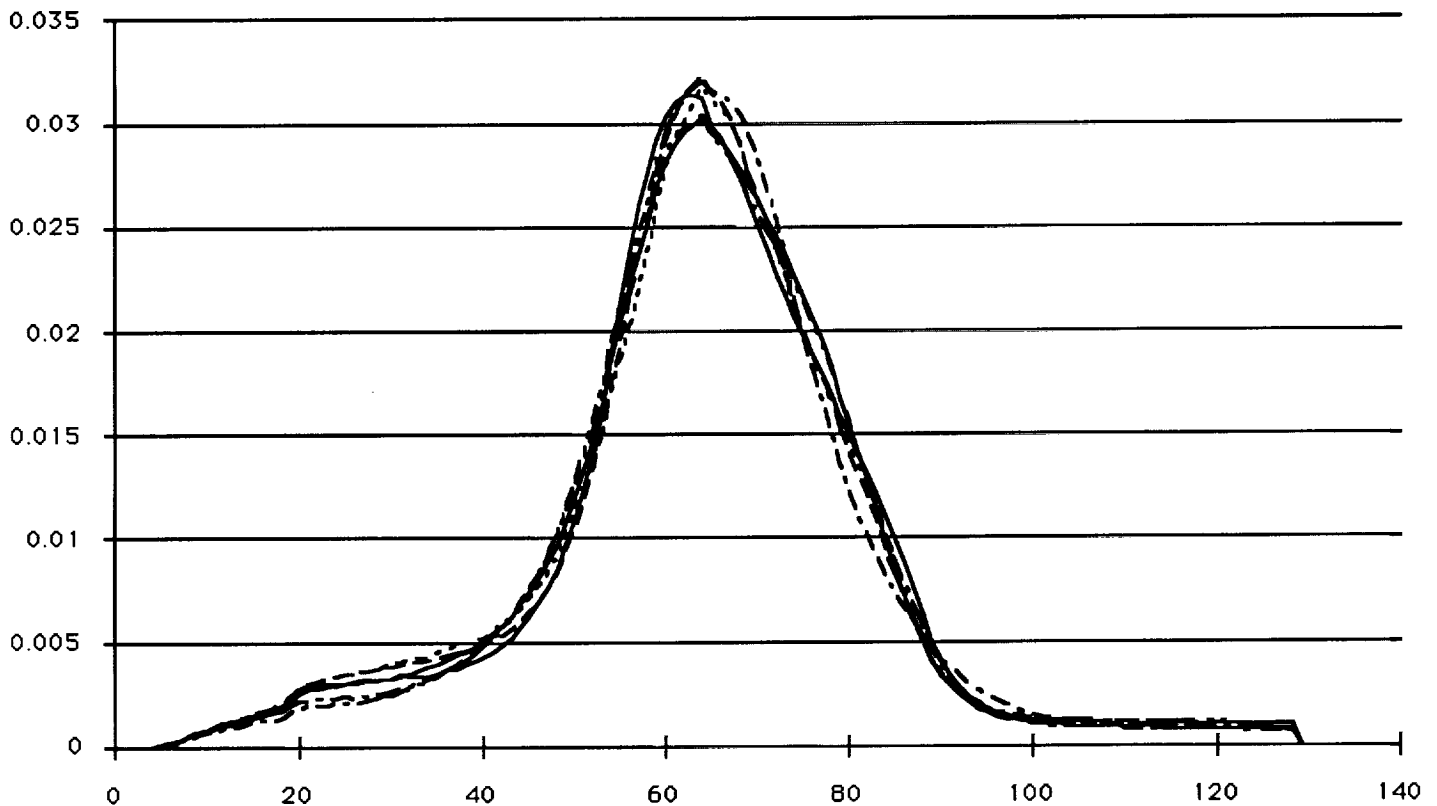

Figure 6— Andromeda Gamma Normalized Data Profiles

Figure 6 is a consolidation of several profiles of the star taken over a 15 minute interval and normalized to the total number of counts in each profile. With Andromeda Gamma centered on the optical axis of the profiler, we selected a 5x microscope objective and acquired a sequence of data profiles of 1000 scans each. These scans were obtained at a rate of 25 scans per second. Comparing this figure to Figure 3, you will notice that the shoulder phenomenon is not nearly as pronounced in this data set.

Over the course of the evening, we took several data samples of Andromeda Gamma, interleaved with data from a nearby apparently singular reference star Perseus Beta Algol, a magnitude 2.14 star. Figure 7 is a consolidation of several profiles of Perseus Beta Algol. As in the case of the Andromeda Gamma data set, these profiles were taken over a 15 minute interval and normalized to the total number of counts in each profile. Comparing this figure to Figure 6, you will notice that the shoulder phenomenon is not present at all.
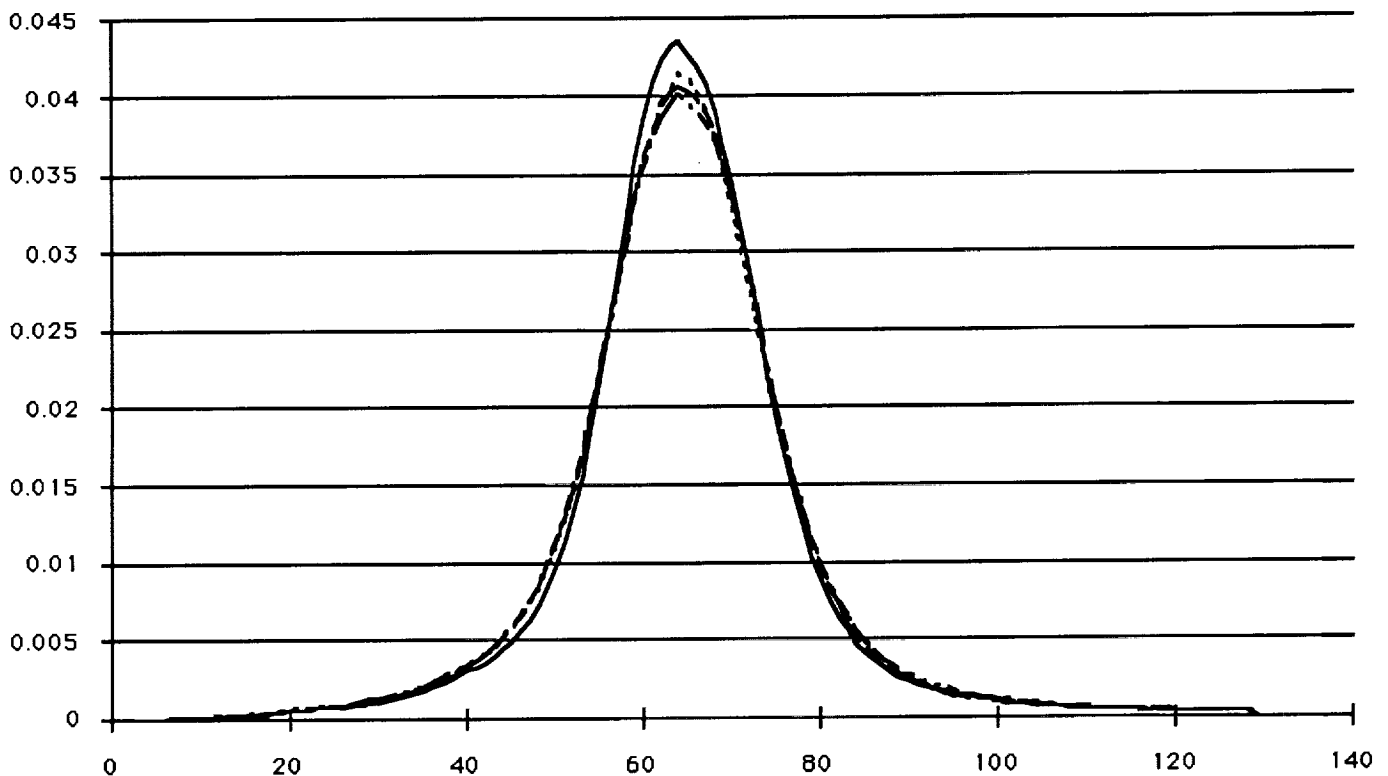
Figure 7— Beta Algol Normalized Data Profiles

Figure 8— Beta Algol Screen Shot

⌘ **File   Edit   Data   Image   Utilities**   2:00:25 ⑦ ▲

REFERENCE STAR- 90*

Counts

Bin Number

| Object: REFERENCE STAR- 90* | Scans: 1000 | Scans/Sec: 25 | Mag/Filter: Calibration Mirror | Counts: 747619 | Peak: 27951 | PPPS |
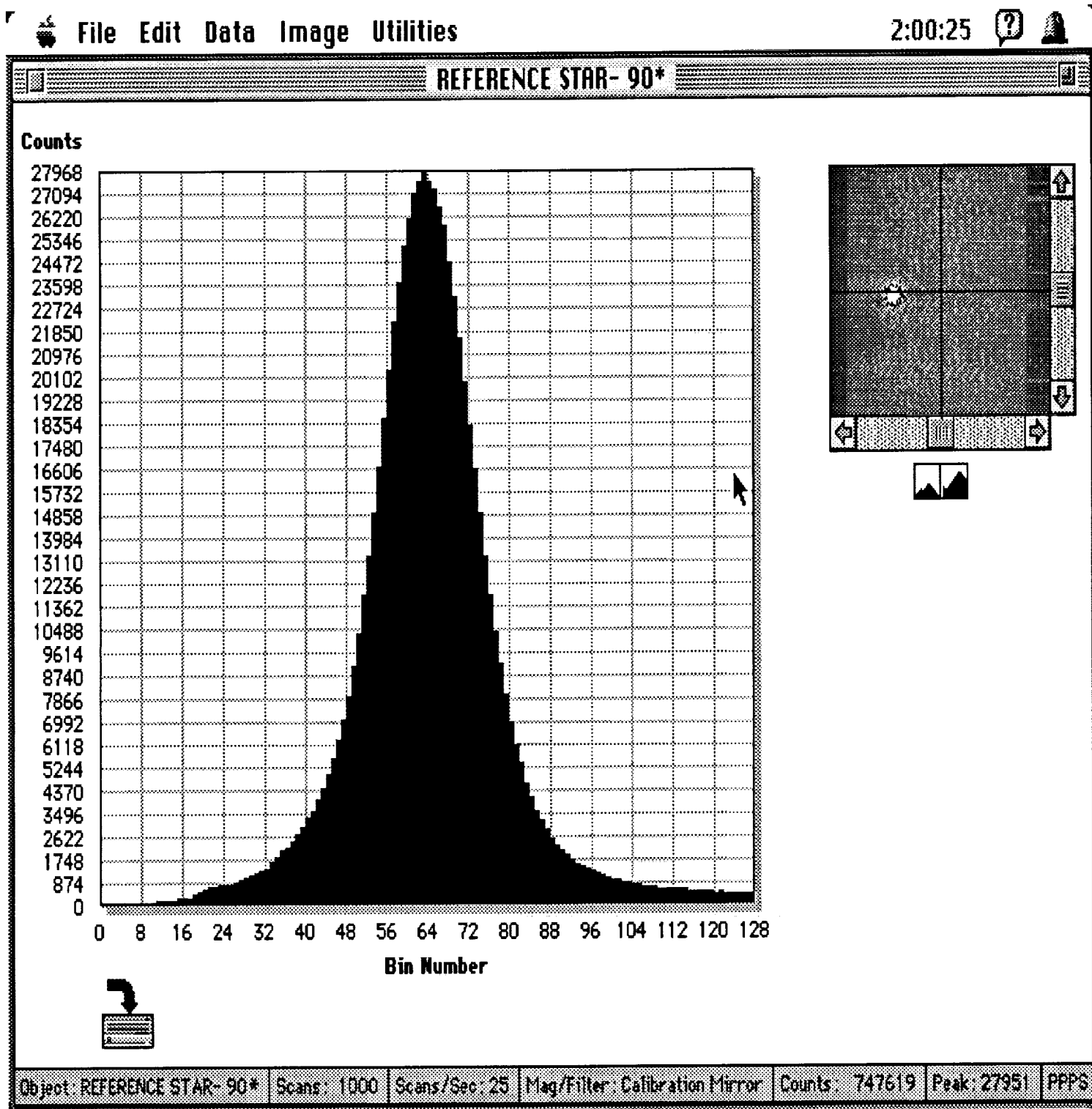
Finally, Figure 8 is a screen shot of the reference star, Perseus Beta Algol. This figure clearly demonstrates each of the solutions to the problems presented in early data trips. The image of the previously out of focus star is now a sharp image (compare with Figure 4). The profile clearly indicates a modest number of noise counts in the wings of the profile, as well as the absence of the shoulder phenomenon to the data.

Convinced that we had eliminated several key sources of digital noise in the instrument, and buffeted by some very strong winds, we closed the dome, packed up the instrument and returned to San Diego to process the data we had gathered.

2.8 Post Processing of the Data

The software developed under this program writes ASCII data files to disk. Two separate software programs were developed to post process the data. The codes are provided in Appendix B and C.

Since we had taken hundreds of data sets of the test and reference stars, we needed a way to determine which data would be the most useful to us. We developed a code that parsed through the data and determined the ratio of the number of counts in the central 28 bins to the total number of counts. This software would process all the data files in a single run and make a report providing the file name and the ratio. Using this report we selected the top ten percent of the data runs as our candidates.

The actual data analysis software, located in Appendix C, reads in data from the test star and the reference star and normalizes the data. The normalized data sets are Fourier transformed and the spectral content of the reference star is subtracted from that of the test star. The residual information is inverse Fourier transformed. Figure 9 is typical of the residual profile information.

The analysis software also does a cross correlation of the two data profiles. During the next month, we plan to use the results of the cross correlation to determine the offset in the test profile due to the secondary. The offset will be used to correct the asymmetric nature of the profile seen

Figure 9— Residual Data Profiles

Arcseconds
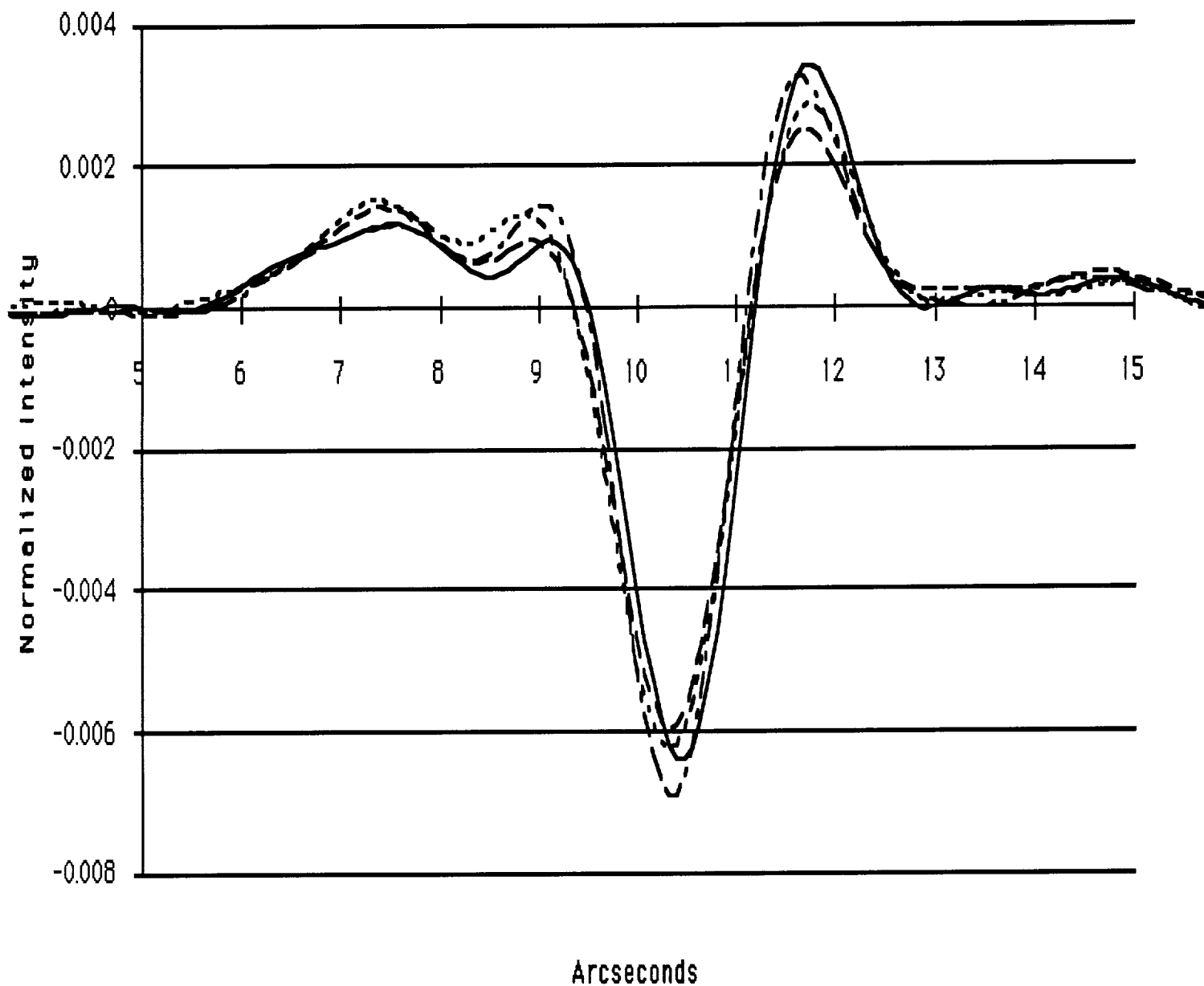
in Figure 9. A new profile will be generated using spectral content of the test star and the newly offset reference star. This profile should contain the companion only and provide information regarding its magnitude and relative position.

3.0 Significant Changes in Organization, Method of Operation, Project Management Network or Milestone Chart

None.

4.0 Problem Areas Affecting Technical/Scheduling Elements

During the course of the last quarter's activities, there were several problem areas affecting the technical elements of this project.

4.1 Electrical Brown-out

As mentioned in section 2.2, an electrical brown-out condition during the first week of our observing schedule affected the technical goals of this project. The resident astronomer was sensitive to our needs and arranged a second and third week of observing to enable us to obtain the necessary data.

4.2 Inclement Weather

Throughout all three trips to Table Mountain, bad weather and poor seeing conditions interfered with our data gathering plans. The only clear sky we had during the three nights, we had close to four arcsecond seeing. Ultimately, high winds forced us to close the dome.

5.0 Name and Phone number of Persons Preparing this Report

Elena Morris, (619) 755-0700 ext. 106
Graham Flint, (619) 755-0700 ext. 122

```c
/********************************************************************
Selector.c

This file will determine the files that we will use to process our data.

********************************************************************/

#include <stdio.h>
#include <math.h>
#include <stdlib.h>
#include <time.h>
#include <OSUtils.h>

void input(void);
void calculate(void);
void output(void);

        FILE     *gRawData1, *gData;
        char     gFilename1[255];
        float    gStrehl;
        double   gArray1[138],gArray2[138];

main()

{
    int i,n;

    printf("Enter the number of files you wish to evaluate\n");
    scanf("%d",&n);

    for(i=1;i<=n;i++)
    {
    input();
    calculate();
    output();

    fclose(gRawData1);
    fclose(gData);
    }

}

void input()
{

float    factor;

    /*  Prompt user for the filename of the old data    */

    printf("Enter the name of the file you wish to evaluate\n");
    scanf("%s",gFilename1);

    /* Open a file to read data */
```

```
        gRawData1=fopen(gFilename1,"r");

        /* Open·a file to read data */
        gData=fopen("The List","a");


}


void calculate()
{
        int        i,j,k,inc;
        int        n=256;
        char       words1[255],words2[255], holder1[20],holder2[20];
        char       numholder1[20],numholder2[20];
        float      total1,midtotal1;
        double     bin1[140],bin2[140];

        i=j=k=0;
        total1=midtotal1=0;

        for(i=0;i<=136;i++)
        {
            if(i<=8)
            {
                fgets(words1,128,gRawData1);
            }
            else if (i>=100)
            {
                fgets(holder1,4,gRawData1);
                fgets(numholder1,8,gRawData1);

                bin1[i-8]=atof(holder1);
                gArray1[i-8]=atof(numholder1);
                total1 = total1 + gArray1[i-8];
            }
            else
            {
                fgets(holder1,3,gRawData1);
                fgets(numholder1,8,gRawData1);

                bin1[i-8]=atof(holder1);
                gArray1[i-8]=atof(numholder1);
                total1 = total1 + gArray1[i-8];
            }

        }

        k=28;

        midtotal1 = midtotal1 + gArray1[64];

        for(j=1;j<=k/2;j++)
```

```
        {
                midtotal1 = midtotal1 + gArray1[64-j];
                midtotal1 = midtotal1 + gArray1[64+j];
        }
        gStrehl=midtotal1/total1;
}


void output()
{
    long        seconds;
    DateTimeRec Date;
    int         j,n;

    GetDateTime(&seconds);
    Secs2Date(seconds,&Date);

    fprintf(gData,"Run Conducted on %2d/%2d/%2d at %2d:%2d\n",Date.month,Date.day,Date

    if(gStrehl>=0.8)fprintf(gData,"Good Data from %10s\t with Strehl Intensity Ratio o

}
```

```
/*********************************************************************
CrossCorr.c

This file determines the crosscorrelation between any two sets of data
from TMO.  We will use this information to determine the signal characteristics
of the binary and compare them to the reference star.

*********************************************************************/

#include <stdio.h>
#include <math.h>
#include <stdlib.h>
#include <time.h>
#include <OSUtils.h>

void input(void);
void calculate(void);
void output(void);
void twofft(float *data1, float *data2, float *fft1, float *fft2, int n);
void four1(float *data1, int nn, int isign);
void realft(float *data1, int n, int isign);
void correl(float *data1, float *data2,int n,float *ans);
void mdian2(float *x,int n,float *xmed);


        FILE    *gCorrData, *gRawData1, *gRawData2;
        char    gFilename1[255],gFilename2[255],gFilename3[255];
        float   gCorr[512],*gMedian;
        float   gNewData[256],gNewerData[256],gData1[256],gData2[256],gTransform1[512],gTr
        double  gArray1[138],gArray2[138],gBin1[256],gBin2[256];

main()

{
    int i,n;

    printf("Enter the number of files you wish to evaluate\n");
    scanf("%d",&n);

    for(i=1;i<=n;i++)
    {
    input();
    calculate();
    output();

    fclose(gCorrData);
    fclose(gRawData1);
    fclose(gRawData2);
    }
}

void input()
{
```

```
float    factor;


      /*  Prompt user for the filename of the old data     */

      printf("Enter the name of the first file you wish to convert\n");
      scanf("%s",gFilename1);

      /*  Prompt user for the filename of the old data     */

      printf("Enter the name of the second file you wish to convert\n");
      scanf("%s",gFilename2);

      /* Open a file to read data */
      gRawData1=fopen(gFilename1,"r");

      /* Open a file to read data */
      gRawData2=fopen(gFilename2,"r");


      /* Open a file to write data     */
      gCorrData=fopen("StarData","a");
}


void calculate()
{
      int          i,j,k,inc,lifesaver1,lifesaver2;
      int          n=256;
      char         words1[255],words2[255], holder1[20],holder2[20];
      char         numholder1[20],numholder2[20];
      float        total1,total2,Diff,check1,check2,flag1,flag2;


          fprintf(gCorrData,"Correlation of stellar data taken from Digital Image Profil
          i=j=k=0;
          total1=total2=0;

          for(j=0;j<=136;j++)
          {
              if(j<=8)
              {
                  fgets(words1,128,gRawData1);
                  fgets(words2,128,gRawData2);

                  fprintf(gCorrData,"%s %s",words1,words2);
              }
              else if (j>=100)
              {
                  fgets(holder1,4,gRawData1);
                  fgets(numholder1,8,gRawData1);
```

```
                    fgets(holder2,4,gRawData2);
                    fgets(numholder2,8,gRawData2);

                    gBin1[j-8]=atof(holder1);
                    gArray1[j-8]=atof(numholder1);
                    total1 = total1 + gArray1[j-8];

                    gBin2[j-8]=atof(holder2);
                    gArray2[j-8]=atof(numholder2);
                    total2= total2 + gArray2[j-8];

                }
                else
                {
                    fgets(holder1,3,gRawData1);
                    fgets(numholder1,8,gRawData1);

                    fgets(holder2,3,gRawData2);
                    fgets(numholder2,8,gRawData2);

                    gBin1[j-8]=atof(holder1);
                    gArray1[j-8]=atof(numholder1);
                    total1=total1 + gArray1[j-8];

                    gBin2[j-8]=atof(holder2);
                    gArray2[j-8]=atof(numholder2);
                    total2=total2 + gArray2[j-8];

                }

        }

        for(k=1;k<=256;k++)
        {
            if(k<=64)
            {
                gData1[k]=0;
                gData2[k]=0;
            }
            else if (k>=193)
            {
                gData1[k]=0;
                gData2[k]=0;
            }
            else
            {
                gData1[k]=gArray1[k-64]/total1;
                gData2[k]=gArray2[k-64]/total2;
            }

        }

        twofft(gData1,gData2,gTransform1,gTransform2, n);
```

```
        correl(gData1,gData2,n,gCorr);

        for(j=1;j<=n;j++)
        {

        Diff = fabs(gTransform1[j] - gTransform2[j]);

            if(Diff >= 0.02 )
            {
            gNewData[j] = gTransform1[j] - gTransform2[j];
            }
            else
            {
            gNewData[j] = 0.0;
            }

        }

        realft(gNewData,n/2,-1);

        check1 = 0.0;
        check2 = 0.0;
        flag1 = 0.0;
        flag2 = 0.0;

        for(j=1;j<=n;j++)
        {
        gBin2[j] = ((1.0/n) * (10e-5) * j)/(4.85e-6);
        gNewData[j] = (1.0/n) * gNewData[j] ;
        }

}


void output()
{
    long        seconds;
    DateTimeRec Date;
    int         j,n;

    GetDateTime(&seconds);
    Secs2Date(seconds,&Date);

    fprintf(gCorrData,"Run Conducted on %2d/%2d/%2d at %2d:%2d with median %g\n",Date.

    n=128;

    fprintf(gCorrData,"Arcseconds\t Correlation\t Raw Data = %6s\t Raw Data = %6s\t No

    for(j=1;j<=n*2;j++)
    {
        if(j<=n/2)
```

```
            {
                fprintf(gCorrData,"%g\t%f\t",gBin2[j],gCorr[n+j]);
                fprintf(gCorrData,"%g\t%g\t%g\t%g\t",gArray1[j],gArray2[j],gData1[j+64],gD
                fprintf(gCorrData,"%f\t%f\t%f\n",gTransform1[j],gTransform2[j],gNewData[j]
            }
            else if(j> n/2 && j<= n)
            {
                fprintf(gCorrData,"%g\t%f\t",gBin2[j],gCorr[n+j]);
                fprintf(gCorrData,"%g\t%g\t%g\t%g\t",gArray1[j],gArray2[j],gData1[j+64],gD
                fprintf(gCorrData,"\t\t%f\n",gNewData[j]);
            }
            else
            {
                fprintf(gCorrData,"%g\t%f\t\t\t\t\t\t\t\t%f\n",gBin2[j],gCorr[j-n],gNewData
            }
        }

    }
```

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